Buckling transition in wall-bounded hydrodynamic crystals

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Complex structural transitions occur in flow driven confined quasi-two-dimensional systems of microspheres. In our recent investigations [1,2] we have observed unusual stability of ordered particle monolayers in channel flow, motion of defects in a particle lattice, flow-induced order-disorder transitions, and fingering instabilities. All these nonlinear dynamical phenomena occur in the Stokes-flow regime as a result of interparticle hydrodynamic coupling.

In our presentation we will analyze novel structural transformations in perturbed periodic square arrays of microspheres in parabolic flow between two parallel walls. We find that a perturbed array is initially stabilized by the swapping-trajectory mechanism [3] causing the particles to fluctuate between faster and slower streamlines in such a way that particle collisions do not occur. The fluctuations slowly decay in time, and the array achieves nearly perfect rectangular order.

Surprisingly, after the fluctuations have dissipated, the particle lattice undergoes a sudden instability resulting in formation of a disordered phase with string-like particle correlations. We explain the transition in terms of a buckling instability producing coherent vertical displacements of particle rows. At the earlier stages of evolution such coherent displacements are prevented by the particle lattice fluctuations, which thus have a stabilizing effect. Consequences of our finding for the dynamics of particle and drop arrays in microfluidic channels will be discussed.

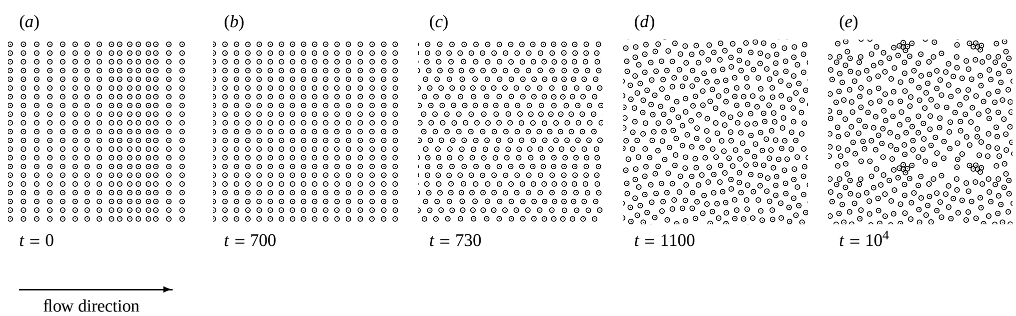

Figure 1: Stages of evolution of an infinite quasi-2D particle array in a parallel-wall channel.

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